Journal of Nusantara Studies 2021, Vol 6(1) 242-264
Universiti Sultan Zainal Abidin
ISSN 0127-9386 (Online)
http://dx.doi.org/10.24200/jonus.vol6iss1pp242-264

A CASE STUDY OF NEEDS ASSESSMENT OF SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATICS (STEM) EDUCATION IN LOWER SECONDARY SCHOOLS

[*1]Loh Su Ling, [2]Vincent Pang & [3]Denis Lajium

[1] Sekolah Menengah Kebangsaan Perempuan Sandakan,
90000 Sandakan, Sabah, Malaysia.
[2,3] Universiti Malaysia Sabah, Jalan UMS,
88400 Kota Kinabalu, Sabah, Malaysia.
*Corresponding author: lohsuling@gmail.com

Received: 10 June 2020 Accepted: 20 November 2020

ABSTRACT

Background and Purpose: Science, Technology, Engineering and Mathematics (STEM) education in the formal school curriculum can be described as a STEM-related individual subject; as a learning package offering learning pathway for STEM elective subjects and as an integrated STEM learning approach. This study focuses on the needs assessment of STEM education as a learning approach among lower secondary school teachers in a local district in Malaysia. The current and desired situations were analysed as well as the causal factors which guide the choice of any intervention programs to address the actual needs.

Methodology: Three schools were selected through heterogenous purposive sampling. The teachers from each school were selected through criterion sampling based on predetermined criteria. 31 teachers from the lower secondary level who teach STEM related subjects as well as the head of panel and departments of the STEM subjects, were selected as the participants. Focus group and one-to-one interviews were conducted with the participants after receiving their consent.

Findings: There is a gap between the desired situation and the current situation in the implementation of integrated STEM education. The implementation of STEM education at the lower secondary level can be facilitated through various means such as a comprehensive STEM education professional development or training for teachers, collaborations between STEM subjects teachers through lesson studies or professional learning community, and working together with local STEM expertise or community of practice.

Contributions: The findings provide relevant information and guidance on the selection of intervention for the integrated STEM education in addressing the needs. It also initiates the planning of the integrated STEM education programs which focuses on the gaps as the means to achieve the desired results.

Keywords: STEM education, needs assessment, case study, gap, interventions

Cite as: Loh, S. L., Pang, V., & Lajium, D. (2021). A case study of needs assessment of science, technology, engineering and mathematics (STEM) education in lower secondary schools. *Journal of Nusantara Studies, 6*(1), 242-264. http://dx.doi.org/10.24200/jonus.vol6iss1pp242-264

1.0 INTRODUCTION

One of the learning approaches highlighted in the new Secondary School Standard Curriculum (Kurikulum Standard Sekolah Menengah, KSSM) in Malaysia is known as Science, Technology, Engineering and Mathematics (STEM) education. There are three descriptions of STEM education in the formal school curriculum: as a STEM-related individual subject; as a learning package offering learning pathway for STEM elective subjects and as an integrated STEM learning approach (MOE, 2016). The description of STEM education as discrete STEM subjects and learning package has a long-standing in the previous and current curricula. More importantly, the definition of STEM education as an approach that is integrated with STEM content, skills, and values in solving a contextual problem is in agreement with the literature (Kim, Chu, & Lim, 2015; Jolly, 2017; Kelley & Knowles, 2016; Roberts, 2012; Truesdell, 2014; Xie, Fang, & Shauman, 2015).

However, this approach may not be familiar to a great number of educators in Malaysia; hence, relevant guidelines and resources are provided to assist educators in implementing the integration of STEM as an approach in classroom teaching and learning. For instance, the general guidelines and several teaching plan samples are presented in the Implementation Guidelines for STEM Education in Teaching and Learning by MOE (2016) with the aim of assisting teachers to carry out the integrated STEM education during class or co-curricular activities. Apart from that, the application of STEM education as an approach is in the recent STEM resource modules for upper secondary subjects, namely Physics, Chemistry, Biology, Additional Mathematics, Computer Science, and Design and Invention (Rekacipta) (BPK, 2017a, 2017b, 2017c, 2017d, 2017e, 2017f). Overall, it is crucial to understand that the comprehensive resource aims to assist the teacher for pre, during, and post-teaching and learning session. On the other hand, the modules can benefit the students through the emphasis on the application of the design process and scientific inquiry which are considered as the main approaches in solving contextual issues. The degree of STEM content and skills integration in each subject tends to vary depending on the issues or problems posed for each topic. On another note, the design of the series serves as a model that can be adopted by teachers in developing their STEM education material for other topics in the future. These resource modules are among the initial resources available for the teachers at the time of writing.

Nevertheless, a documented study on the implementation and effectiveness of these modules are deemed necessary considering that teachers may not have a clear understanding of how to effectively deliver the integrated STEM education approach. Furthermore, there has been no reliable evidence on teachers STEM pedagogical content knowledge (PCK) in conducting the integrated STEM education at the point of writing. Hence, this may lead to "curriculum bandwagon" in which teachers may end up carrying out the integrated STEM education lessons or programs without proper training, analysis, and planning due to the desire to be a part of national and global education scenario. Therefore, it is crucial to assess the gap in the implementation of integrated STEM education as an approach to learning for the purpose of enabling more programs or interventions to be planned in the attempt to address the needs. Otherwise, all the activities, programs, and projects will only be carried out without fulfilling the real needs, thus making it impossible to achieve the desired results which will only lead to a waste of time, resources, and human efforts. Therefore, the current research presents a qualitative case study of a needs assessment of STEM education among lower secondary school teachers in a local district in Malaysia. Specifically, the present study seeks to answer two research questions described as follows: (1) What are the gaps in the implementation of STEM education in the lower secondary level? and (2) What are the problems identified in the implementation of STEM education in the lower secondary level? Overall, the findings of this study are expected to provide relevant information and guidance on the selection of intervention for the integrated STEM education in addressing the needs. Other than that, this study also aims to provide an effective method that can initiate the planning of the integrated STEM education programs which focuses on the gaps as the means to achieve the desired results. More importantly, the replication of this procedure can be used to plan similar integrated STEM programs for teachers and students in school.

Journal of Nusantara Studies 2021, Vol 6(1) 242-264 ISSN 0127-9386 (Online)
http://dx.doi.org/10.24200/jonus.vol6iss1pp242-264

2.0 LITERATURE REVIEW

2.1 STEM Education

There are two main general definitions of STEM educations which are as disciplinary subjects and as integrated approach to solve real world problems. In describing STEM education as STEM disciplinary subjects, it can be further defined as individual STEM subjects or a combination or package of STEM subjects. The second definition, which is the focus of this paper, is to view STEM education as an approach that blends the STEM disciplines to solve a real world problem (Kim et al., 2015; Jolly, 2017; Kelley & Knowles, 2016; Roberts, 2012; Truesdell, 2014; Xie et al., 2015). The general purpose of STEM education is for students to apply the integrated concepts of STEM education to solve contextual issues. Specifically, NRC and NAE (2014) listed five goals of STEM education for students which are STEM literacy, twenty-first century competencies, STEM workforce readiness, interest and awareness as well as the ability to make connections among STEM disciplines.

For educators, STEM education aims to increase STEM pedagogical content knowledge (PCK) in order to see the change in teaching practice. This will facilitate in achieving the desired outcomes for teachers and students. In order for students to develop the right concepts, teachers need to be equipped with substantial knowledge about the topics involved. For instance, in order to find solution for contextual problems which are usually ill-defined, it may involve different aspects of science, mathematics, engineering and/or technology. Therefore, teachers' STEM subject content knowledge is important to guide students to apply the correct concepts and skills to solve the problem. Teachers must also have the right orientation in terms of their belief and attitude towards the goals and outcomes of integrated STEM education for the students. Without the proper understanding of the definition especially with regards to the nature and scope of integration, as well as the goals of integrated STEM education, teachers may end up in misconception or carrying out the STEM education as the usual individual STEM subject teaching and learning. Figure 1 presents the descriptive framework of integrated STEM education proposed by the U.S. National Academy of Engineering and National Research Council, listed the goals, outcomes, implementation as well the nature and scope of integration (NRC & NAE, 2014).

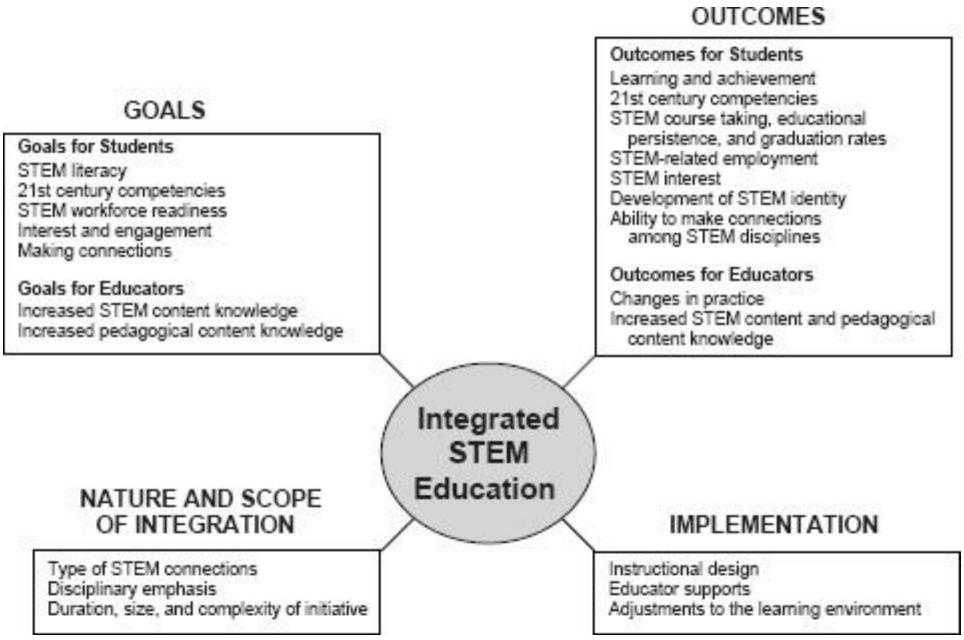

Figure 1: Descriptive Framework of Integrated STEM Education

(NRC & NAE, 2014, p. 32)

2.2 Needs Assessment

In needs assessment, it is important to understand that needs refer to the gaps in the result, consequences, or accomplishments between the current and desired situations (Altschuld & Kumar, 2010; Kaufman, Rojas, & Mayer, 1993). Besides, needs assessment is described as a systematic process that can identify the gaps between the current situation and desired situation by emphasising the gaps and selecting the most important ones that need to be addressed (Altschuld & Kumar, 2010; Kaufman & English, 1979; Kaufman et al., 1993). The main purpose of assessing needs is to identify the most crucial issues that need to be solved by providing the required data to formulate the right solutions or interventions to bridge the gap (Altschuld & Kumar, 2010; Kaufman & English, 1979; Watkins, Meiers, & Visser, 2012). Overall, it can be clearly understood that needs assessment acts as a guide and justification for the decisions made which are expected to improve and accomplish the desired results (Watkins et al., 2012). However, needs assessment in education is not a curricular innovation but an empirical process that determines the needs for an intervention (English & Kaufman, 1975). In short, needs assessment identifies the gaps between the current and desired situations to guide the choice of any intervention programs to address the actual needs of the situation as well as achieve the desired results (Figure 2).

ISSN 0127-9386 (Online)
http://dx.doi.org/10.24200/jonus.vol6iss1pp242-264

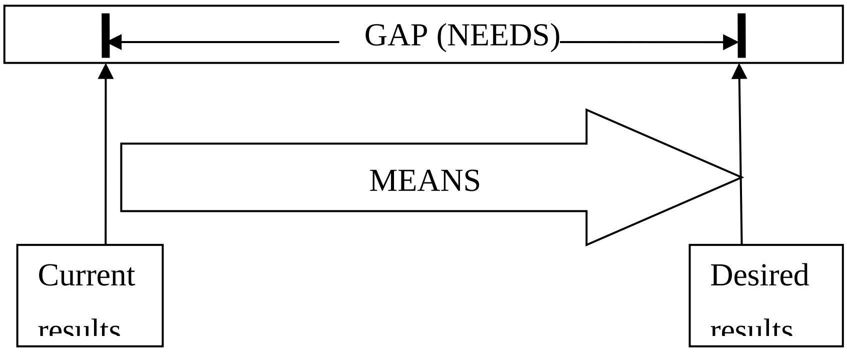

Figure 2: Needs Assessment

(Kaufman et al., 1993)

On another note, the objectives of educational interventions can be identified when the information about the learner is compared with certain desirable standards or acceptable norms; hence, these differences are described as needs (Tyler, 1949). Accordingly, it is important to have measurable statements about the desired conditions in comparing with the current situations in the attempt to perform the needs assessment. In this case, the measurable desired conditions refer to educational goals or objectives that are related to students learning behaviour (English & Kaufman, 1975). The sources of goals can be derived from activities, programs, or curriculum standard documents. However, the planning, derivation, validation, prioritisation, and translation of the goals require time, resources, and involvement of a great number of educational experts and stakeholders. In particular Yoder, Bodary, and Johnson (2016) recommended the goals and objectives of STEM education need to be formulated from the top-down approach starting with the local STEM advocates and policymakers. Hence, clear, relevant, and validated goals and objectives will be able to set a clear direction for educators to effectively implement STEM education programs. However, there is an absence of clear, agreeable, and measurable STEM education goals and performance objectives at the point of writing. Furthermore, it is beyond the capacity of the researchers as well as the scope of the present study to formulate the goals and measurable performance objectives for STEM education. Hence, the present study intends to subscribe to the generic goal of integrated STEM education that is established in the STEM Reinforcement Initiatives (MOE, 2018b) which is "to produce STEM-literate students who have the potential to identify, apply, and integrate the STEM components or concepts to understand and solve problems creatively and

Journal of Nusantara Studies 2021, Vol 6(1) 242-264 ISSN 0127-9386 (Online)
http://dx.doi.org/10.24200/jonus.vol6iss1pp242-264

innovatively through integrated STEM learning in real-world context" as the desired situation in this needs assessment.

Concerning this, Watkins et al. (2012) further describe the three-step process involved in a basic needs assessment which is to identify, analyse, and decide. This is to ensure that the assessment focuses on the following matters: (1) results before solutions, (2) needs are analysed before making decisions, and (3) decisions are justified. Generally, this involves identifying the gaps, analysing the causal factors, and deciding the intervention. Therefore, the needs assessment employed by the present study will initially identify the gap between the current and the desired situations, followed by the analysis of the causal factors that lead to the gaps (Figure 2). On a final note, the current research will provide several suggestions on the interventions that may address the gaps identified in this study.

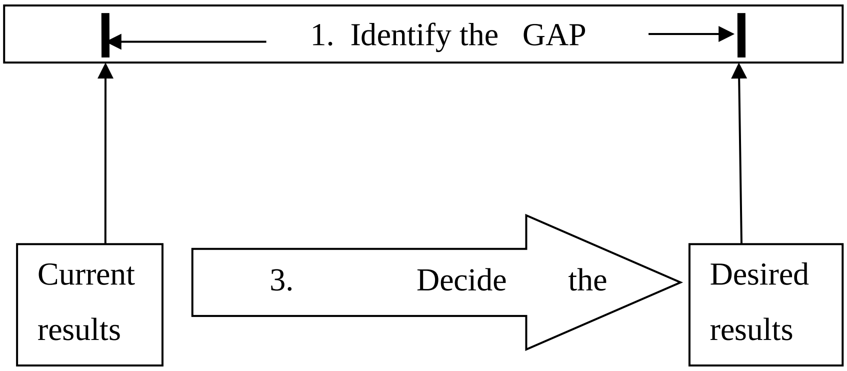

Figure 2: Steps in Needs Assessment

3.0 RESEARCH DESIGN

The current context evaluation adopted a qualitative case study. The heterogenous purposive sampling strategy which is also known as maximum variation sampling by Patton (2002) was utilised for the selection of the schools. It focuses on describing common themes that cut across a small sample of great diversity. In particular, a total of three schools were selected based on the average school grade (*Gred Purata Sekolah, GPS*) ranking of a standardised examination known as Malaysian Certificate of Education (*Sijil Pelajaran Malaysia, SPM*) in the district. The GPS index provides an indication of the heterogeneity in terms of academic performance among the schools. Accordingly, school A was identified as the top-performing school, followed by school B which is ranked in the 10th place, and lastly, school C that is ranked last in the list. The basic profile of the school is shown in Table 1.

Table 1: Basic Profile of The Selected Schools

Description	**School A**	**School B**	**School C**
2017 SPM GPS index	3.67	5.74	6.75
Number of students	723	793	1750
Number of teachers	50	52	102
Number of classrooms	22	25	31
Student composition	All girls	Boys and girls	Boys and girls
Teaching session	One session	One session	Two sessions

Meanwhile, the teachers from each school were selected through criterion sampling based on predetermined criteria, which is individual STEM subject teachers in the lower secondary level as well as the head of panel and department of the STEM subjects. In the case of the current research, 31 teachers from the lower secondary level who teach Science, Mathematics, Design of Technology (*Rekabentuk Teknologi*, RBT), and Basic Computer Science (*Asas Sains Komputer*, ASK), as well as the head of panel and departments of the STEM subjects, were selected as the participants for this study. Besides, it should be noted that the RBT teachers were selected because the content and skills in RBT subject are similar to the engineering design process (EDP). Apart from that, the aspect of technology is included in the curriculum standard of RBT and ASK. A focus group discussion and one-to-one interviews were conducted with the participants after receiving their consent. Specifically, the interviews were conducted in the Malay language based on a semi-structured interview protocol (Appendix 1), while the interview participants are presented in Table 2.

Table 2: Interview Participants

Participants in School A	Participants in School B	Participants in School C
• RBT teacher (RA) • Science teacher 1 (SA1) • Science teacher 2 (SA2) • Science teacher 3 (SA3) • Science teacher 4 (SA4) • Mathematics teacher (MA1) • Mathematics teacher (MA2) • Science teacher 2 (SA2) • Science teacher 4 (SA4) • ASK teacher (AA)	• Head of RBT panel (RPB) • Head of Science Panel (SPB) • Head of Mathematics Panel (MPB) • Science teacher (SB) • Mathematics teacher 1 (MB1) • Mathematics teacher 2 (MB2) • RBT teacher (RB) • Head of Science and Mathematics Department (SMDB) • ASK teacher (AB) • Science teacher (SB) • Mathematics teacher (MB1)	• Head of Science and Mathematics Department (SMDC) • Head of Technic and Vocational Department (TVDC) • Science teacher 1 (SC1) • Science teacher 2 (SC2) • Science teacher 3 (SC3) • Mathematics teacher 1 (MC1) • Mathematics teacher 2 (MC2) • RBT teacher 1 (RC1) • RBT teacher 2 (RC2) • ASK teacher (AC)

The present study also performed document analysis to reveal the needs and problems involved in the implementation of integrated STEM education in the lower secondary level. In this case, the documents include the curriculum standards developed by the Ministry of Education (MOE), and yearly teaching plan (*Rancangan Pengajaran Tahunan*, RPT) for Form One Science, Mathematics, RBT, and ASK of the schools. Accordingly, the interview transcripts were coded manually by assigning specific codes to label meaningful units which contained the insights related to the research questions. Next, the excerpts of the interviews were then translated from the Malay language into English.

4.0 ANALYSIS AND DISCUSSION

The findings of the present study are further divided into two sections to address the two research questions of this study. In particular, the first question seeks to understand the gap between the current and desired situations regarding the implementation of STEM education in the lower secondary level, while the second question aims to understand the causal factors that lead to the gaps.

4.1 Gap Between the Current and Desired Situations

The description of the gap focuses on the implementation of the integrated STEM program. It is important to note that there is a gap between the desired situation and the current situation in the implementation of integrated STEM education. The findings from the interviews revealed that all three schools have not carried out any specific STEM programmes involving the integration of STEM subject that is aimed to solve the contextual problem at the time of the interview. The yearly teaching plans of the individual STEM subjects for the three schools indicated the lack of planning for specific STEM activities. Apart from that, the subjects are not explicitly integrated into the teaching and learning process. Overall, it is safe to say that all three schools agreed with the lack of integration between Science, Mathematics, RBT and ASK.

Other than that, the content of the subjects is taught separately, while the course work projects are carried out according to the individual subjects as prescribed by the curriculum standards. Furthermore, the teachers seem to be uncertain about the nature and definition of the integrated STEM education as portrayed in the conversation below:

Researcher	:	*Is there any STEM projects or programs implemented in this school?*
SPB	:	(Quiet and thinking for a moment)…. *I think none. We have students' coursework…is that considered a (STEM) project?*
Researcher	:	*Can you describe a bit about that especially in form one level*?
SPB	:	*Because in KSSM science, coursework project is 20%, yes we have projects*.
Researcher	:	*Does the project have any explicit integrated STEM elements*?
SPB	:	(Thinking for a moment…) *It is just a presentation project.*
RPB	:	*If specifically, there seems to have no integrated STEM elements*.

(Focus Group Interview / School B)

Regarding this matter, projects in the form of activities tend to be carried out for the individual subjects, particularly during class teaching time or academic week. Moreover, most of the projects are in the form of classroom activities that are aimed to apply or enhance the understanding of relevant content and skills for a particular topic by not only focusing to solve the contextual problem.

In short, there is no explicit mention of integrated STEM programmes or projects based on the findings obtained from the interviews and document analysis. Meanwhile, the focus of the projects or course works for individual STEM subjects to solve contextual problems has not been emphasized in teaching and learning. Instead, projects are carried out in the fulfilment of the syllabus requirement with the main purpose of enhancing and applying the understanding of a particular topic or area of the subject. Thus, there has not been any implementation of the STEM education programme that focuses on the integration of STEM subjects as well as the process of solving the contextual problem. Therefore, the existence of a gap in the implementation of integrated STEM education in the lower secondary level is undeniable in this context.

Table 3: The Gap in The Implementation of STEM Education in The Lower Secondary Level

Current situation	Desired situation
No implementation of a STEM education programme that focuses on STEM subjects' integration and solving the contextual problem.	Implementation of STEM education program to produce STEM-literate students who have the potential to identify, apply, and integrate the STEM components or concepts in the attempt to understand and solve problems creatively and innovatively through integrated STEM learning in a real-world context.

4.2 Causal Factors

Other than that, the teachers also pointed out some of the reasons why STEM education has not been properly implemented in schools as summarised in Appendix 2. Specifically, the codes for the causal factors are 'not sure about STEM education', 'do not know the content', 'do not know how to teach', 'teachers do not know other STEM content', 'examination orientated', ' content-driven', ' lack of STEM expertise', and ' lack of facilities'.

The interview revealed that the teachers are uncertain about STEM education itself. For example, teachers AA, SMDB, and TVDC were not convinced about STEM education as well as its purpose in the teaching and learning process even though the briefings by the district education officers have provided basic information about STEM education as an approach. Hence, this clearly reflects the lack of the right orientation, particularly in terms of their belief and attitude towards the goals of integrated STEM education as a learning approach. As a result, teachers may end up to misunderstand and misconduct STEM education as the usual individual STEM subject teaching and learning without the proper understanding of the definition and purpose of integrated STEM education. Regarding this matter, a few of the interviewees especially the RBT teachers admitted that they do not have the content knowledge to teach their subject because it was only introduced in 2017. For instance, RA, an RBT teacher admitted that she is not equipped with sufficient knowledge in science and other STEM disciplines, thus preventing her to effectively carrying out STEM education. Apart from content knowledge, the teachers also stated that they are clueless on how to deliver STEM education through an integrated approach. For instance, a Science teacher mentioned that she does not know how to apply STEM education in her teaching (SC1), while a Mathematics teacher has no idea on how to integrate the subjects in her teaching (MB2). This indicates a lack of STEM education pedagogical knowledge among the teachers as well as limited collaborations among the teachers. Meanwhile, a science teacher admitted that she is not aware of the content of other STEM subjects, thus making it difficult for them to integrate the content (SA1). On another note, the participants also mentioned the lack of STEM expertise such as qualified engineering teachers who can relate some of the contents with the real-world situation as one of the causal factors. For example, the RBT teacher (RPB) lamented that he does not have the engineering qualification to teach about building construction in a real-life context.

Besides, the content-driven and examination orientated nature of the teaching and learning in school has led to time constraint for the planning and implementation of any STEM programs in the school. In the case of the present study, teachers from the three schools agreed that their teaching mainly focuses on completing the specified content only to prepare their students for the examinations. Teachers have to prepare lessons and maximise the classroom teaching time to complete the required content as well as drill the students to prepare for their examination. Hence, this has reduced the time to think, plan, and implement any integrated STEM projects or even the current coursework projects for individual STEM subjects.

The limited availability of facilities and resources is seen as another obstacle in the implementation of the integrated STEM programs. In most cases, teachers have been struggling to teach with limited facilities and resources in the classroom and laboratory even for individual subjects. For example, a science teacher (SB) mentioned that the insufficient amount of materials and apparatus tend to prevent every student from experiencing hands-on inquiry-based learning. In addition, the lack of tools and equipment is also prevalent in technical subjects such as RBT and ASK which further hinders the students from carrying out the projects, particularly in RBT subject. Hence, RBT teacher (RC2) resolved by conducting a demonstration using video clips after introducing the basic theories without any hands-on activities. Similarly, the ASK teachers, namely AB and AC complained about the lack of computers, laptops, LCDs, and other tools such as microprocessor kits, which limits their ability to teach effectively. For instance, AC mentioned that he had to use the whiteboard to teach which is not appropriate for the current content, thus preventing the students from having a hands-on learning experience. There was a sense of frustration as the teachers shared their views regarding the problems and challenges involved in the implementation of the integrated STEM education as well as their STEM discipline. The summary of the codes and teachers' excerpts that describe the problems in the implementation of STEM education in lower secondary level is presented in Appendix 2.

4.3 Implications

This section discusses the implication of the findings by suggesting several interventions that can be adapted to address the gaps in the implementation of STEM education in the lower secondary level. As previously mentioned, the lack of STEM education pedagogical content knowledge (PCK) among teachers has been considered as one of the main causal factors in the current needs assessment. The results revealed that the teachers have inadequate knowledge about the content of STEM subjects, instructional strategies, and orientation on the integrated STEM education which are regarded as the components of PCK as described by Grossman (1990). Hence, the lack of PCK may hinder the implementation and effectiveness of integrated STEM education among the students. In this case, effective teachers who know how to integrate the available curriculum standards, develop, and deliver the hands-on project-based instruction are considered as the backbone to the implementation of innovative STEM education (Yoder et al., 2016). Hill, Rowan, and Ball (2005) mentioned that teachers' knowledge of a particular subject is directly related to the learning and achievement of students. More importantly, this is considered as a crucial factor that determines whether the integrated STEM education programmes or lessons can be carried out well either during formal classroom learning or after-school settings (NRC & NAE, 2014).

According to Nadelson et al. (2013), a considerable number of educators may be unprepared with limited content knowledge in STEM subjects as well as having lack of confidence and efficacy to carry out integrated STEM education programme. In this case, content knowledge among teachers is discovered to be positively correlated to their efficacy (Nadelson et al., 2013; Park & Oliver, 2008; Schoon & Boone, 1998). Moreover, it should be noted that the efficacy of teachers is dependent on their STEM subject matter knowledge as well as the ability to transfer the concepts and skills to the students through the choice of instructional strategies (NRC & NAE, 2014). Specifically, students are likely to develop misconceptions in the related concepts when teachers have low efficacy in teaching any concepts or skills (Schoon & Boone, 1998). With regards to science instruction, Grossman (1990) stated that educators need to have pedagogical knowledge that is able to facilitate the instructions of lessons or programmes which include the right orientation in the subject, instructional strategies, assessment, knowledge about the students, and the current subject curriculum standards. In addition, it is crucial to know how to assist students in mastering the essential concepts in the individual STEM discipline while making explicit connections between them (NRC & NAE, 2014). For example, a great number of teachers are not competent in carrying out project-based learning (PjBL) in regard to the implementation of the integrated STEM education lessons or programs (Erdogan & Bozeman, 2015). Furthermore, they may not be familiar with managing students in such a way that allows them to effectively engage in projects with complex tasks. Subsequently, this may lead to negative attitudes towards PjBL. In terms of assessment, Erdogan and Bozeman (2015) mentioned that most STEM teachers are unable to perceive students' realistic products and solution to real-world problems as a form of formative and summative assessment. In most cases, they end up relating the assessment with the usual high stakes testing in schools or public examination. Hence, a teacher's feeling of uncertainty about his or her abilities due to the inadequacy of STEM subject matter knowledge and the knowledge about the appropriate instructional strategies may be manifested through their reduced confidence in teaching the related concepts. In other words, they are less likely to believe that they can teach effectively, which then leads to students' misconceptions. Therefore, it is crucial for teachers to acquire the necessary PCK in the integrated STEM education, especially in terms of the content knowledge as well as pedagogical knowledge considering that these may increase the self-efficacy of teachers and ultimately promote effective learning among the students.

Nevertheless, teachers may have limited ability to deliver an effective or meaningful integrated STEM lesson or programme if they never had the chance to experience learning science, mathematics, engineering and technology in an integrated manner through the application of the integrated concepts and skills to solve a contextual problem (NRC & NAE, 2014). Therefore, teachers need to undergo comprehensive training in the implementation of integrated STEM education programs. Professional development in integrated STEM education is one of the interventions that can address the gap identified in the present study. For example, in-service teachers can increase their PCK by specifically integrating STEM through on-going professional development or training programs. Data from several studies showed that the on-going teachers' development programme positively affect teachers' efficacy, confidence, and motivation in teaching STEM education (Benuzzi, Golez, Grace, Hamm, & Straits, 2015; Bissaker, 2014; Nadelson et al., 2013; Slavit, Nelson, & Lesseig, 2016; Stohlmann, Moore, & Roehrig, 2012). A professional development program that is extended over a period of time such as one week or more, together with an on-going support system and mentoring are found to be more effective (NRC & NAE, 2014). Kelley and Knowles (2016) suggested that teachers must be equipped with a conceptual understanding of integrated STEM approach. Apart from that, Erdogan and Bozeman (2015) further describe that the professional development for STEM requires the teachers to focus on pedagogical methods that are aligned with authentic assessment for students. In other words, teachers need to learn how to assess students' realistic products or solution to the real-world problem formatively and summatively. More importantly, teachers have to receive trainings on how to manage, guide, and facilitate students' decision making and problem-solving through PjBL. Other than that, Daugherty (2008) mentioned that hands-on activities, teacher collaboration, and instructor credibility are the aspects that contribute to the effectiveness of the integrated STEM professional development. In short, an effective integrated STEM professional development consists of hands-on learning of integrated STEM education lessons, the focus of instructional strategies in facilitating students' learning and assessment especially in PjBL, that extended over a period of time with on-going mentoring and support from credible instructors.

On a more important note, there is also a need to collaborate with other STEM expertise from universities or any higher learning institution or community of practice for extra and specific training in a particular STEM field. Collaborations with the local community of STEM expertise or practitioners may assist the teachers and students to be transited from a novice understanding towards the mastery of concepts, skills and practices, especially in technology. The engagement of the local community of STEM experts such as engineers, practising scientists, agriculturists, and technologists may facilitate the learning around real-life contexts that are grounded on common shared practices regardless of the pedagogical approach (Kelley

& Knowles, 2016). However, cautions need to be taken in selecting STEM experts or organisations that will be involved in the collaboration efforts. Hence, teachers and school administration have to ensure that every knowledge is appropriately shared and in line with the integrated STEM education learning approach among the students considering that not every student can learn in this particular type of social setting. Apart from that, there may be organisations that are willing to collaborate with schools to promote specific education products or programs, in which the teachers and school administrator may be obliged to purchase or commit to the products and programs. For example, there may be STEM educational products or programs that only require passive assembly and do not explicitly integrate the STEM subject content as well as the need to solve a contextual problem. In this case, students are allowed to complete the activity without the need to apply the essential concepts and skills of the integrated STEM approach. Therefore, a certain amount of discernment is required to judge the type of collaboration, particularly regarding whether it will meet the teachers or the students' needs in integrated STEM education.

Besides, the emphasis of standardised examinations in schools seems to take up all the effort and focus of teachers in teaching and learning. Generally, most of the resources and time seem to be geared towards achieving the desired results in the standardised examinations and other administrative works. This requires the teachers to spend most of their time preparing and completing the required curriculum standards before drilling the students for the examinations. In this case, it should be noted that all of these are influenced by school policies, visions, practices, and administration leadership. Moreover, it is undeniable that schools are governed by the policies and practices of the district and state education departments, including the Ministry of Education of each country. Similarly, parental and community expectations also play an important role in influencing the schools' norms and practices (NRC & NAE, 2014). For instance, there is an emphasis on the grades and results in the standardised examinations, particularly concerning the need for securing scholarships and placement in local college and universities. Hence, this seems to drive the schools to perform well in the various examinations. However, the Ministry of Education Malaysia is slowly gearing towards holistic education which indicates that students will not be streamed according to their academic achievements beginning in 2018. Schools are advised not to place great emphasis on school rankings based on the Average School Grade. Apart from that, the Ministry of Education also intends to reduce the administrative work of teachers to allow them to have more time to prepare and implement teaching and learning activities as stated in the '12 Initiatives in Schools' (MOE, 2018a). Therefore, it is hoped that teachers, school administrator, parents, and the community will shift toward holistic teaching and learning to allow more time to conduct student-centred learning activities such as integrated STEM education program considering that these changes require time. Other than that, the 12 new initiatives for the schools established by the Ministry of Education is also committed to addressing the lack of facilities and resources. More importantly, the aim is to focus on the necessary educational investments and infrastructure repairs in schools. In other words, it aspires that the educational investments will facilitate the implementation of integrated STEM education, especially in supplying laboratory and technological tools and equipment. Therefore, further work should be conducted regarding the aspects that might hinder or advance the implementation of the integrated STEM education which may go beyond the scope of this writing.

On a more important note, there is abundant room for further progress in designing and developing more integrated STEM education training for different groups of teachers such as pre-schools, primary, secondary, and pre-university level. Also, longitudinal studies can be conducted to determine its effectiveness in increasing the PCK and efficacy of teachers as well as students learning in integrated STEM education. Further research should be undertaken to investigate the integrated STEM education lesson studies or any professional learning community (PLC) at the school level. Moreover, lesson study is a type of research by itself that focuses on education innovation intending to improve the process of teaching and learning. As previously mentioned, a collaboration between different STEM subjects' teachers may assist in the effective delivery of the integrated STEM instruction. In terms of direction for future research, further work on any integrated STEM education professional development program or training for teachers should be carried out in determining how it affects the PCK and efficacy of teachers in the teaching and implementation of the integrated STEM lessons or programs.

5.0 CONCLUSION

The present study managed to identify the gap in the implementation of integrated STEM education. Specifically, it was revealed that integrated STEM education programs have not been implemented in the selected schools. In this case, it should be noted that the pedagogical content knowledge of teachers is one of the main issues in the implementation of the integrated STEM education in and outside the classroom. Furthermore, it was discovered that the teachers are not familiar with the integration, approach, and application of STEM subjects content in solving contextual problems. Also, there is a lack of STEM expertise among teachers. On another note, content-driven and examination orientated culture in the school have caused the teachers to allocate more time and effort in completing the curriculum standards as well as drilling and preparing the students to face the high-stakes standardised examinations. The lack of resources and facilities were also discovered as one of the challenges in teaching and learning of individual STEM subjects. Overall, the findings suggested the need for comprehensive STEM education professional development or training, collaborations between STEM subjects teachers through lesson studies or professional learning community as well as working together with local STEM expertise or community of practice to facilitate the implementation of STEM education in the lower secondary level.

REFERENCES

Altschuld, J. W., & Kumar, D. D. (2010). *Needs assessment. An overview.* Sage Publications, Inc.

Benuzzi, S., Golez, F., Grace, L., Hamm, D., & Straits, W. (2015). *continuum for integrating STEM in teacher preparation and induction.* LBUSD & CSULB.

Bissaker, K. (2014). Transforming STEM education in an innovative Australian school: The role of teachers' and academics' professional partnerships. *Theory into Practice*, *53*(1), 55.

BPK. (2017a). *Siri bahan sumber sains, teknologi, engineering dan matematik (STEM). BSTEM Biologi*. Kementerian Pendidikan Malaysia.

BPK. (2017b). *Siri bahan sumber sains, teknologi, engineering dan matematik (STEM). BSTEM Fizik*. Kementerian Pendidikan Malaysia.

BPK. (2017c). *Siri bahan sumber sains, teknologi, engineering dan matematik (STEM). BSTEM Kimia*. Kementerian Pendidikan Malaysia.

BPK. (2017d). *Siri bahan sumber sains, teknologi, engineering dan matematik (STEM). BSTEM Matematik Tambahan*. Kementerian Pendidikan Malaysia.

BPK. (2017e). *Siri bahan sumber sains, teknologi, engineering dan matematik (STEM). BSTEM Rekacipta*. Kementerian Pendidikan Malaysia.

BPK. (2017f). *Siri bahan sumber sains, teknologi, engineering dan matematik (STEM). BSTEM Sains Komputer*. Kementerian Pendidikan Malaysia.

Daugherty, J. L. (2008). *Engineering-oriented professional development for secondary level teachers: A multiple case study analysis*. Utah State University.

English, F. W., & Kaufman, R. A. (1975). *Needs assessment: A focus for curriculum development*. Association for Supervision and Curriculum Development.

Erdogan, N., & Bozeman, T. D. (2015). Models of project-based learning for the 21st century. In A. Sahin (Ed.), *A practice-based model of STEM teaching* (pp. 31–42). Sense Publisher.

Grossman, P. (1990). *The making of a teacher: Teacher knowledge and teacher education*. Teachers College Press.

Hill, H. C., Rowan, B., & Ball, D. L. (2005). Effects of teachers' mathematical knowledge for teaching on student achievement. *American Educational Research Journal, 42*(2), 371–406.

Jolly, A. (2017). *STEM by design. Strategies and activities for grades 4 – 8.* Routledge.

Kaufman, R., & English, F. W. (1979). *Needs assessment. Concept and application*. Educational Technology Publications.

Kaufman, R., Rojas, A. M., & Mayer, H. (1993). *Needs assessment. A user's guide.* Educational Technology Publications.

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education, 3*(1), 1-11.

Kim, Y., Chu, H.-E., & Lim, G. (2015). Science curriculum changes and STEM education in east Asia. In M. S. Khine (Ed.), *Science education in east Asia: Pedagogical innovations and research-informed practices* (pp. 149–226). Springer International Publishing.

MOE. (2016). *Panduan pelaksanaan sains, teknologi, kejuruteraan dan matematik (STEM) dalam pengajaran dan pembelajaran.* Kementerian Pendidikan Malaysia.

MOE. (2018a). 12 inisiatif terbaru peringkat sekolah. Retrieved from https://www.moe.gov.my/index.php/my/arkib/pemberitahuan/2018/4580-12-inisiatif-terbaru-peringkat-sekolah

MOE. (2018b). *Inisiatif pengukuhan pendidikan STEM*. Bahagian Perancangan dan Penyelidikan Dasar Pendidikan.

Nadelson, L. S., Callahan, J., Pyke, P., Hay, A., Dance, M., & Pfiester, J. (2013). Teacher STEM perception and preparation: Inquiry-based STEM professional development for elementary teachers. *The Journal of Educational Research, 106*(2), 157–168.

NRC & NAE. (2014). *STEM integration in K-12 education*. National Academies Press.

Park, S., & Oliver, J. S. (2008). Revisiting the conceptualisation of pedagogical content knowledge (PCK): PCK as a conceptual tool to understand teachers as professionals. *Research in Science Education, 38*(1), 261–284.

Patton, M. Q. (2002). *Qualitative research & evaluation methods.* Sage Publications, Inc.

Roberts, A. (2012). A justification for STEM education. *Technology and Engineering Teacher, 71*(8), 1–5.

Schoon, K. J., & Boone, W. J. (1998). Self-efficacy and alternative conceptions of science of preservice elementary teachers. *Science Education, 82*(5), 553–568.

Slavit, D., Nelson, T. H., & Lesseig, K. (2016). The teachers' role in developing, opening, and nurturing an inclusive STEM-focused school. *International Journal of STEM Education, 3*(1), 1-7.

Stohlmann, M., Moore, T., & Roehrig, G. (2012). Considerations for teaching integrated STEM education. *Journal of Pre-College Engineering Education Research, 2*(1), 28–34.

Truesdell, P. (2014). *Engineering essentials for STEM instruction.* ASCD.

Tyler, R. W. (1949). *Basic principles of curriculum and instruction.* Chicago University Press.

Watkins, R., Meiers, M. W., & Visser, Y. L. (2012). *A guide to assessing needs: Essential tools for collecting information, making decisions, and achieving development results*. World Bank.

Xie, Y., Fang, M., & Shauman, K. (2015). STEM education. *Annual Review of Sociology, 41*(1), 331–357.

Yoder, S., Bodary, S., & Johnson, C. C. (2016). Effective program characteristics, start-up, and advocacy for STEM. In C. C. Johnson, E. E. Peters-Burton, & T. J. Moore (Eds.), *STEM road map. A framework for integrated STEM education* (pp. 211–237). Routledge.

APPENDIX 1

Interview Protocol Guide (Open-ended questions)

Interview questions/ guide	**Interview questions/ guide (BM)**
Is there any STEM education program implemented in this school? If yes: Describe the program Students' interest and participation The learning of science and mathematical concepts and also STEM practices Teachers' readiness If No: Problem/ challenges Suggestions	*Adakah sebarang program STEM yang telah dijalankan di sekolah ini?* *Jika ya:* *-Terangkan program tersebut* *-Minat dan penglibatan pelajar* *- Pembelajaran pelajar dari segi konsep sains, matematik, amalan-amalan STEM.* *-Kesediaan guru* *Jika tidak:* *-Masalah/ cabaran* *-Cadangan*
STEM education is an approach that integrates science, Mathematikc, engineering and technology in solving contextual problem STEM subjects integration Current status Problems/ challenges Opportunities/ suggestions Contextual problem solving Current status Problems/ challenges Opportunities/ suggestions	*Pendidikan STEM merupakan pendekatan pembelajaran yang mengintegrasi kan Sc, Math, kejuruteraan dan teknologi dalam menyelesaikan masalah sebenar/ kontekstual.* *a. Integrasi subjek-subjek dalam STEM* *i. Status sekarang* *ii. Masalah/ cabaran* *iii. Peluang/ cadangan* *b. Penyelesaian masalah sebenar/ kontekstual* *i. Status sekarang – kemahiran pelajar* ii. Masalah/ cabaran iii. Peluang/ cadangan

APPENDIX 2

Causal Factors in The Implementation of STEM Education in Lower Secondary Level

Themes	Codes	Teachers' excerpts
Lack of STEM pedagogical content knowledge	Not sure about STEM education	" *If regarding STEM, I am not very sure. I only knew about it in this school, because there is no STEM in my previous school. Maybe because we don't have enough room. In this school we have a special room for STEM."* (AA) " *STEM education is good, but in terms of implementation, we are not very sure about it*." (SMDB) "*We had briefing about STEM education, but it is not sufficient for us to implement it in classroom. We only know the surface and basic information."* (TVDC)
	Do not have the knowledge	"*Yes, in fertigation project (one topic in RBT), it has all the STEM element especially technology and engineering in agriculture field, but we do not have the knowledge to teach*" (RB) "*RBT involved projects such as brief project, pictorial sketching, fertigation technology, fashion designs. We do not have the knowledge on how to teach the students, we do not have the skills…"* (RB) "*As for me, I am teaching RBT, I do not know much about science, I only know some very basic science…*". (RA)
	Do not know how to integrate	"*I am a science teacher and just started to teach this KSSM subjects this year. I still do not know how to apply STEM in my classroom teaching."* (SC1) "*For me I still do not know to integrate the subjects*". (MB2) "*The problem is, this thing is still quite new. We still teach according to the previous, we just follow the DSKP. If regarding integration, we are still do not see it yet*." (SMDB)
Time constraint	Content driven	" Yes, we are teaching according to the syllabus, if we focus too much of activities, our syllabus cannot be completed. That's the problem." (RA) "We have limited time in the classroom because we need to cover the syllabus and sometimes only left a few minutes to think about STEM" (SC1)
	Examination oriented	"My heart is divided, I want to give them drills, at the same time I want them to enjoy. But here, we are bound by the syllabus and the exams that need to be covered" (RA) " Firstly, above everything, the syllabus must be completed, because students need to sit for exams" (RPB)
Lack of teachers' collaboration	Teachers do not know others STEM content	"*The problem is that we have never seen their books (RBT) and they also never seen our books (science), and we find it hard to match, unless we go for training and relearn everything. Yes the problem is we haven't cross each others' content yet, so it is quite difficult to integrate*". (SA1)

Lack of STEM expertise	No engineering qualification	*"....we want to teach engineering, but the teachers are language teachers, sound not logical. As for science and technology, they are still manageable, but not engineering. How can we teach the students? The buildings will collapse. We don't have the qualification. The school must have at least one teacher who is certified in this field so that we can teach the students in a proper way. Now, all we depend is on the internet as our reference." (RPB)*
Lack of facilities	Lack of teaching facilities	*" We did not do many projects. As said just now, we are lacking of facilities. What we can do is just teach the basic theory, then show a video. That is all we can do. To carry out projects, we seem not able to do that yet." (RC2)* *" For us here, our computers are same ones since the year 2004 until now, no change. So, we can see all the plans are very good, but in terms of implementation and facilities…you can look at them yourself, the learning environment, the classrooms, the facilities. Sometimes, teachers have to buy own LCDs. The content we are teaching now no longer suitable for chalk and talk. A lot of the notes and teaching material require graphics. So, the lack of equipment…I feel sad, if possible we want to achieve the learning objectives, whatever we teach, let the students be able to grasp. But now, students are at a lost. We are also sad to see this." (AC)* *"For example, the form two syllabus (ASK) regarding a circuit computer kit, Phyton. We only have a few. In order for students to do a project, every students need to have one. We are lack of that. There is no budget allocation for this" (AB)* *"Our chemical and apparatus are not sufficient. For example I teach and conducted experiments to be carried out in five groups. We only have three crucibles. Then there was once I conducted an experiment but failed because the chemicals have expired" (SB)*